Resolution aspects affecting acidification factors

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Summary

Acidification is still an important environmental burden that needs attention. Even nowadays large parts of central Europe (e.g. the Netherlands, Germany, and Poland) are heavily acidified.
In this study European acidification, *A*, is expressed as "area of unprotected ecosystem in Europe". An ecosystem is an area with uniform soil, vegetation, and organisms, like a forest or grassland. "Protected" and "unprotected" are terms used to indicate whether or not an ecosystem is harmed by the acidifying deposition it receives. When the SO_2, NO_x, and NH_3 deposition on an ecosystem exceed the so called critical load of that ecosystem, the ecosystem is "unprotected". Otherwise it is "protected" against acidification. This approach enables a quantification of the environmental effect acidification.
Extended (integrated assessment) models determine acidification, *A*, resulting from emissions originating in European countries. However, these models require much computing time. Traditionally, acidification factors (AFs) linearly relate national emission changes (ΔE) to changes in European acidification (ΔA): $\Delta A = AF \cdot \Delta E$. For each country and each substance a separate AF exists. AFs can fasten acidification calculations, enabling for example real time computations during negotiations on emission reductions. Life cycle assessment (LCA) uses AFs to determine the acidifying impact from a product or service. AFs should approximate acidification with a reasonable accuracy and should be generally applicable. They should not depend heavily on model parameters like resolution.

This report deals with the research question: how do AFs depend on spatial resolutions of emission and deposition, sector specific emissions, and grid cell specific emissions. We also try to indicate which kind of AFs, considering calculation method and ΔE range, are to be preferred (considering the previously listed model parameters).
Emissions and deposition resolution specific AFs relate ΔE from one country to ΔA in Europe. These national AFs are calculated with different emission and/or deposition resolutions of the extended model. Sector specific AFs relate ΔE from one economic sector within a country to ΔA in Europe. Using the national AFs instead of sector specific AFs will probably produce less accurate results when studying the influence of emission reduction within just one economic sector. Grid cell specific AFs relate ΔE from a certain grid cell of 50x50km^2 to ΔA in Europe. Such AFs can be used to accurately determine the acidifying impact of emissions from a specific location (or small area).
The current study considers AFs resulting from two different calculation methods and three ΔE ranges. Ideally AFs do not depend on model parameters. A low sensitivity of AFs to emission/deposition resolution, sector specific emission, and grid cell specific emissions is preferable. The linearization error related to applying AFs instead of the extended model is important as well. Not only is a low value of the error wanted for optimal AFs but also a low sensitivity of the error to the model parameters.
To answer the research questions we calculate ΔA for given ΔE, using different emission and deposition resolutions in the extended model. ΔE ranges from -50% to +20% with steps of 1%. AF equals the slope of a straight line through these points.

In general it turned out that AFs depend in a non-systematic way on emission and deposition resolutions. Variations in AFs and linearization errors strongly correlate to the occurrence and size of so called “jumps”. Each ΔE step of 1% causes a step in ΔA. Some ΔA-steps are considerably larger than average; these are called “jumps”. The size of ΔA-steps is determined by the number of ecosystems changing their state from “protected” to “unprotected” (or the other way around) and the area of these ecosystems. A step size of zero occurs when the change in deposition on the European ecosystems does not cause a change of the state of any of these ecosystems. This happens when deposition reductions (resulting from emission reductions) are too small to flip an ecosystem from “unprotected” to “protected”, when ecosystems are highly exceeding their critical load and requiring a very large deposition reduction to change their state, or when the ecosystems were already “protected”. When the ΔA-step is not zero, the minimum situation is that one ecosystem changes its state. In that situation the ΔA-step equals the area of this single ecosystem. The current research showed that often “jumps” are mainly caused by just one large ecosystem changing its state. Therefore, a smaller maximum size of ecosystems would result in smaller variations in AFs and smaller linearization errors.
Both, sector and grid cell specific AFs deviate from the national AFs. This deviation is caused by a number of aspects including different absolute emission amounts. Grid cell specific AFs could not be calculated in a satisfying way applying the used model, because of the very small emission amounts involved. Large ranges of grid cell specific ΔE (expressed as percentage of the grid cell specific emission) caused zero sized ΔA-steps.

For all experiments two methods to compute AFs were applied. AFs calculated using regression and using the Single Value (SV) method were compared. The SV method defines AF as $\Delta A/\Delta E$ at a certain point, we use ΔE = -50%. Regression techniques calculate a straight line through the points while minimizing the error. Theoretically regression AFs should be less sensitive to small variations in the model results. Most experiments in this report support this. Based on theoretical and experimental results we recommend regression AFs because they depend less on the studied model parameters.
Regression AFs are computed over a certain range of emission changes. The report distinguishes regression AFs related to the whole emission range (-50% $\leq \Delta E \leq$ +20%), large emission reduction mainly used in air pollution policy application (-50% $\leq \Delta E \leq$ -20%), and small emission changes mainly appearing in LCA applications (-20% $\leq \Delta E \leq$ +20%). We expected the emission range specific AFs to be better than the AFs for the whole emission range. This effect was only slightly observed. When considering small emission changes, the AF related to -20% $\leq \Delta E \leq$ +20% indeed resulted in smaller errors than the AF related to the whole emission range. However, this emission range specific AF was more sensitive to model parameters.

In LCA the emission range specific AFs could slightly improve the accuracy of the calculated acidification. More important for LCA applications is the possibility to quantify the error. Uncertainty of LCA results has received increased attention lately. However, uncertainty calculations in LCA prefer a quantification of the uncertainty in AF itself, not in the resulting acidification (as was computed in the current research).
Using AFs within air pollution policy is still in its infancy. The use of AFs increases the speed of the calculation of acidification. However, the error in the calculated

acidification also increases. National AFs turned out to be not generally applicable, for example for sector specific emissions, without considerably increasing the uncertainty of the calculated acidification. The report quantifies this uncertainty for some situations. Air pollution policy should weight the increased uncertainty against the gained calculation speed.